LIQUID CRYSTAL DISPLAY WITH INTEGRATED RESISTIVE TOUCH SENSOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to liquid crystal displays (LCD's) employing means for measuring touch position, and, more particularly to LCDs wherein such touch measuring means is integrated into a substrate of the LCD.

2. Description of the Related Art

Touch input systems which determine the location of an object or person touching a surface are utilized in a wide variety of applications and require that the location of the touch be determined with a high degree of accuracy. Typically, these devices are transparent and are fitted directly over a computer display. Examples of such add-on touch screens which can be fitted over a CRT or flat panel display may be found in "You can touch this! Touch screens deliver multimedia to the masses" by C. Skipton, New Media, Feb. 10, 1997, p. 39–42. One disadvantage of add-on touch screens is that they increase the weight and size of the display unit. This weight and size increase is not desirable for portable applications, such as notebook computers. Further, the communications to the computer for the add-on often requires an available card slot, serial port or parallel port adapter.

These disadvantages of using an add-on touch screen can be greatly reduced by the integration of the touch sensor into the LC display. Touch input systems have used a variety of methods for determining the touch location. The two methods which can be integrated into an liquid crystal display with the lowest cost and the fewest modifications are the capacitive and the resistive membrane techniques.

A disadvantage of the capacitive technique is that it requires a tethered stylus for precision input whereas the resistive technique works with a finger or any stylus with an appropriate tip radius.

The resistive membrane technique operates by pressing two conductive layers together and sensing the position of the contact. The general method of operation of "4-wire" and "5-wire" systems are described in "Pen and touch input solutions for portable devices", J. Schuessler in Proc. of the Fourth Annual Portable by Design Conference, Mar. 24–27, 1997, Santo Clara Calif., Penton Publishing, 1997, pp. 473–478. The sensor typically includes two conductive layers separated by insulating spacers where the top sheet is flexible. The bottom sheet can either be a rigid material such as glass or a flexible material such as plastic. The conductive layer is typically an Indium Tin Oxide (ITO) layer which is deposited on the facing surfaces of the plastic and glass layers. The radius of curvature which is needed to press the conductive layers together is determined by the spacing and height of the spacer bumps. (See U.S. Pat. Nos. 3,798,370 and 3,911,215, both incorporated herein by reference). When used directly on a display device, i.e., not as a separate digitizer, the various layers which make up the resistive touch sensor are transparent in the active area. See U.S. Pat. Nos. 4,071,689 and 4,220,815 both incorporated herein by reference.

In the more common 4-wire method, used in the majority of small portable devices with touch input, a uniform voltage gradient is applied to one of the conductive layers and sensed on the second conductive layer (at the point of contact) to determine the touch location in one direction.

The location in the second direction is determined by applying a uniform voltage gradient in the direction perpendicular to the first gradient on the second conductive layer and sensing the voltage on the first conductive layer. By continuously alternating the direction and location of the applied voltage gradient and sensing locations, the touch locations can be determined. An advantage of this method is that the individual conductive layers only need to be "linearized" in one direction. This is typically accomplished by depositing a layer of ITO (or other resistive material) which is substantially uniform in resistivity, and electrodes on the two opposite edges of the ITO coated surface. The electrodes are usually made of a material which is more conductive than the surface, and the electrodes are often silk-screened onto the surface. A major disadvantage of the 4-wire method is that the ITO layer on the flexible top sheet cracks after repeated use which results in nonlinearities in the applied electric field, which causes location errors.

In the 5-wire method, the problem with cracks in the ITO layer on the flexible top sheet is greatly reduced by using the ITO layer on the flexible top sheet only as the sensing layer. This requires that the bottom conductive layer be "linearized" so that uniform voltage gradients can be applied in two orthogonal directions. The general approach used to linearize the electric field is to pattern openings into the ITO layer, deposit a pattern of lower resistivity, or use a combination of both. There is patent literature on such methods for electric field linearization for touch input systems. Typically, 5-wire touch input devices have lifetimes an order of magnitude greater than 4-wire systems and are used for larger screen sizes and usually mounted over CRT displays for kiosk applications. Add-on 5-wire resistive membrane touch screens are available from MicroTouch Systems, Inc. (Methuen, Mass.), Elo TouchSystems, Inc. (Fremont, Calif.), or Carroll Touch, Inc. (Round Rock, Tex.), for example. In all cases, a rigid bottom glass substrate is used on which an electrode pattern is formed around the edge to linearize the electric field. The location sense methods used are somewhat different in the MicroTouch device. A voltage is applied to the conductor on the flexible top sheet. When contact is made, currents flow to the four corners of the sensing (bottom) conductive layer and are measured simultaneously. The contact location is calculated based on that relative current flow in each corner (See U.S. Pat. No. 4,293,734, incorporated herein by reference). The Elo TouchSystems and Carroll Touch devices function similar to the 4-wire device and alternately apply perpendicular field gradients but the gradients are only applied to the linearized resistive layer. The conductive layer on the flexible layer is always used for sensing the contact position (See, U.S. Pat. No. 3,798,370).

The use of a conventional 5-wire resistive membrane overlay touch screen is not acceptable for portable use because of the added size and weight of a glass substrate. If a rigid glass substrate in a conventional system is replaced by a thinner and lighter plastic substrate, the greater compliance of the plastic substrate may result in the linearized ITO layer developing cracks which would reduce the lifetime of the device.

Therefore, a need exists for an integrated resistive touch sensor for liquid crystal displays which is lighter and thinner than conventional devices and provides little or no additional attenuation of light emitted from the display.

SUMMARY OF THE INVENTION

A liquid crystal display with an integrated touch sensor, in accordance with the present invention, includes a first sub-